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Inventor	:	Woo-Sung Han
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For	:	Method And Apparatus For Recording A Hologram From A Mask Pattern By The Use Of Total Internal Reflection Holography And Hologram Manufactured By The Method
Examiner	:	John Juba, Jr. Tel 571-272-2314
Art Unit	:	2872
Docket	:	HOLTR-400

Hon. Commissioner for Patents
PO Box 1450
Alexandria VA 22313-1450

RESUBMISSION OF CLAIMS

Sir:

In response to the October 14, 2004 Notice of Non-Compliant Amendment, Applicant is resubmitting claims with proper identifiers as required.

A favorable action is solicited.

Respectfully submitted.

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Claims 1-6-05

1. (Currently ~~Amended~~) Method of forming a hologram from a information containing mask, comprising the following steps:
- arranging a substrate bearing a layer of a holographic recording medium on a first face of a coupling element and in optical contact therewith;
- arranging a information containing mask in a spaced relationship and parallel to the substrate;
- generating an illumination light beam and then splitting the light beam into an object beam and a reference beam;
- - directing the reference beam to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled
- directing the object beam through the mask to the substrate such that it overlaps with the reference beam in the holographic recording medium;
~~further including the steps of~~
- employing a photoresist as the holographic recording medium; and
- arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially ~~orthogonal.~~
orthogonal; and
- the step of employing a photoresist includes employing a photoresist whose layer thickness is less than 500nm.

2. (Original) Method according to claim 1, characterized in that substantially only the transmission hologram is recorded in the holographic recording layer.

3. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that a photoresist is employed whose refractive index at the exposure

wavelength is greater than 1.6 ~~and preferably greater than 1.7~~.

4. (Previously Amended) Method according to claim 1, characterized in that the plane of polarisation of the object beam is at 45° to the plane of incidence of the reference beam at the holographic recording layer.

5. (Previously Amended) Method according to claim 1, characterized in that the photoresist material is selected such that its thickness (d) and absorption (a) meet the condition
$a * d < 1$.

6. (Previously Amended) Method according to claim 1, characterized in that the photoresist is selected such that its contrast described by its gamma-value satisfies the condition $\gamma < 3$.

7. (Previously Amended) Method according to claim 1, characterized in the photoresist is selected such that its resolution described by the smallest period of grating that can be optically recorded in the material is with a modulation depth $(d_{max} - d_{min})/ (d_{max} - d_{min}) > 25\%$ satisfies the condition $\Lambda < 200$ nm.

8. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that laser light of a wavelength below 300nm~~, and preferably of a wavelength between 150 and 260 nm~~ for recording the hologram is used.

9. (Previously Amended) Method according to claim 1, characterized in the polarisation angles are selected according to the refractive index of the photoresist.

10. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that a combination of polarisation angles of between 37 to 44°~~; preferably 39°~~ for the reference beam and = -43 to -47°~~, preferably -45°~~ for the object beam with respect to the plane of incidence are applied.

11. (Previously Amended) Method according to claim 1, characterized in that the intensity of the reference beam exceeds that of the object beam.

12. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that the intensity of the reference beam exceeds that of the object beam by ~~a factor 2, and preferably is 4 : 1.~~at least a factor 2.

13. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that the intensity ratio of the~~object and~~ reference and object beams is between 3:1 and 5:1~~, and preferably about 4:1~~.

14. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that the thickness of the photoresist layer is ~~less than 500 nm, preferably between 100 and 300 nm and most preferably between 200~~between 100 and 300 nm.

15. (Previously Amended) Method according to claim 1, characterized in that the image recorded in the photoresist as surface relief hologram is transferred into the substrate material by an etching process.

16. (Previously Amended) Method according to claim 1, characterized in that the etching process is a plasma etching process.

17. (Previously Once Amended and Currently Amended) Method according to claim 1, characterized in that the illumination beam~~(51)~~ is scanned in a first direction such that the reference and object beams scan across the holographic recording medium~~(79)~~ and the mask~~(73)~~, respectively , stepping the illumination~~(51)~~ beam in a second direction perpendicular to the first direction, and then scanning the beam ~~(51)~~illumination beam again in the first direction and so on, such that the reference

beam and object beams ~~(75,74)~~ travel simultaneously across the ~~first~~ face ~~of~~ of the substrate ~~(77)~~ in optical contact with the first ~~face,~~ face of the coupling element.

18. (Previously Amended) Method according to claim 1 characterized in that the gap between the holographic recording layer and the mask is determined, e.g. interferometrically, and then the distance between the hologram and the recording medium adjusted to a predetermined value.

19. (Previously Amended) Method according to claim 1 characterized in that in the hologram reconstruction process the distance between the hologram and the substrate onto which the holographically recorded image is to be reconstructed is adjusted to the value as maintained between the holographic recording layer and the mask in the hologram formation process.

20. (Previously Once Amended and Currently Amended) Method according to claim 1 characterized in that the reference beam is directed to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled and so that the angle of incidence of the beam in the recording layer is less than 45°~~, preferably less than 42° and most preferably less than 40°~~.

21. (Previously Once Amended and Currently Amended) Use of the method according to claim 1 for recording features of less than 1 ~~□m, preferably less than 0.5 □m,~~ μm contained in a mask in a hologram for use in microlithography.

22. (Currently Amended) Method of forming a hologram from a information containing mask, comprising the following steps:

- arranging a substrate bearing a layer of a holographic recording medium on a first face of a coupling element and in optical contact therewith;
- arranging a information containing mask in a spaced relationship and parallel to the substrate;

- generating an illumination light beam and then splitting the light beam into an object beam and a reference beam;
- directing the object beam through the mask to the substrate such that it overlaps with the reference beam in the holographic recording medium;

~~further including the steps of~~

- employing a photoresist as the holographic recording medium;
- directing the reference beam to a second face of the coupling element in a way that the condition for total internal reflection at the interface between the recording medium and the ambient medium is fulfilled and so that the angle of incidence of the beam in the recording layer is less than ~~45°, preferably less than 42° and 45°, most preferably less than 40°;~~
- arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are also substantially ~~orthogonal.~~ orthogonal; and
- the step of employing a photoresist includes employing a photoresist whose layer thickness is less than 500nm.

23. (Previously Once Amended and Currently Amended) Method according to claim 22 characterized in that a photoresist is employed whose refractive index at the exposure wavelength is greater than 1.6 ~~and preferably greater than 1.7~~.

24. (Previously Once Amended and Currently Amended) Method according to claim 22, characterized in that substantially only the transmission hologram is recorded in the holographic recording layer.

25. (~~Currently Amended~~) Total internal reflection holographic recording apparatus for recording a hologram from a mask, comprising
- an optical coupling element for receiving a substrate on a first face;

- a substrate bearing a holographic recording medium, the substrate being in optical contact with said first face of the optical coupling element,
- at least one light source for generating a light beam;
- optical means for generating a collimated light beam of a selected cross-section;
- means, e.g. a beam-splitter, prism or the like, for generating two coherent light beams, a reference light beam and an object light beam;
- means for directing the reference light beam at a second face of the coupling element such that it illuminates the interface between the ~~first face and the ambient medium or the interface between a substrate in optical contact with said first face~~holographic recording medium and the ambient medium at an angle greater than the critical angle;
- means for directing the object light beam at the first face of the coupling element such that it is aligned with the reference beam in the plane of the holographic recording medium on the substrate in contact with the first face;

~~characterized in that~~

- the holographic recording medium is a photoresist; and
- means are provided for arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are substantially ~~orthogonal~~orthogonal; and
- said photoresist being a layer having a thickness less than 500nm.

26. (Currently Amended) Apparatus according to claim 25 characterized in that the at least one light source is a laser light source emitting light of a wavelength below 300nm~~; and preferably of a wavelength between about 150 and 260 nm; and preferably between about 190 and 254 nm~~.

27. (Previously Amended) Apparatus according to claim 25, characterized in that the photoresist material is such that its thickness (d) and absorption (a) meet the condition $a * d < 1$.

28. (Previously Amended) Apparatus according to claim 25, characterized in that the photoresist material is such that that its contrast described by its gamma factor satisfies the condition $\gamma < 3$.

29. (Previously Once Amended and Currently Amended) Apparatus according to claim 25, characterized in that a combination of polarisation angles of between 37 to 44°; ~~preferably 39°~~ for the reference beam and - 43 to -47°; ~~preferably 45°~~ for the object beam are applied.

30. (Previously Amended) Apparatus according to claim 25, characterized in that means are provided for adjusting the intensities of the object and reference beams such that the intensity of the object beam exceeds that of the reference beam.

31. (Previously Once Amended and Currently Amended) Apparatus according to claim 25, characterized in that the intensity of the object beam exceeds that of the reference beam by at least of a factor 2 ~~preferably by a factor of about 4~~.

32. (Previously Once Amended and Currently Amended) Apparatus according to claim 25, characterized in that the thickness of the photoresist layer is ~~less than 500 nm, preferably between 100 and 300 nm and most preferably between 200~~between 100 and 300 nm.

33. (Previously Amended) Apparatus according to claim 25, characterized in that means are provided for scanning and stepping the incident light beam in a raster scan across the beam splitting means in a first and in a second direction, respectively, such that the reference and object beams travel simultaneously across the first face or the substrate in optical contact with the first face;

34. (Previously Amended) Apparatus according to claim 25 further comprising

- means for measuring the gap between the hologram and a wafer being arranged in

a spaced relationship to the hologram; and

- means for adjusting the parallelism and/or separation between the hologram and the wafer.

35. (Previously Amended) Apparatus according to claim 25, further characterized in that the directing means for the reference light beam further arranges that the angle of incidence of the reference beam in the holographic recording layer is less than 45°; ~~preferably less than 42° and most preferably less than 40°~~.

36. (Previously Once Amended and Currently Amended) Apparatus according to claim 25 characterized in that the photoresist employed has a refractive index at the exposure wavelength of greater than 1.6 ~~and preferably greater than 1.7~~.

37. (Currently Amended) Total internal reflection holographic recording apparatus or system for recording a hologram from a mask, comprising

- an optical coupling element for receiving a substrate on a first face;
- a substrate bearing a holographic recording medium, the substrate being in optical contact with said first face of the optical coupling element,
- at least one light source for generating a light beam;
- optical means for generating a collimated light beam of a selected cross-section;
- means, e.g. a beam-splitter, prism or the like, for generating two coherent light beams, a reference light beam and an object light beam;
- means for directing the reference light beam at a second face of the coupling element such that it illuminates the interface between the ~~first face and the ambient medium or the interface between a substrate in optical contact with said first face~~holographic recording medium and the ambient medium at an angle greater than the critical angle;
- means for directing the object light beam at the first face of the coupling element such that it is aligned with the reference beam in the plane of the holographic recording medium on the substrate in contact with the first face;

~~characterized in that~~

- the holographic recording medium is a photoresist;
- means are provided for arranging the planes of polarisation of the object and reference beams incident on the holographic recording medium such that their polarisation vectors are substantially mutually orthogonal in the holographic recording medium and such that the polarisation vectors of the incident and totally internally reflected reference beams are substantially orthogonal; and
- in that the directing means for the reference light beam further arranges that the angle of incidence of the reference beam in the holographic recording layer is less than ~~45°, preferably less than 42° and most preferably less than 40°.~~ 45°; and
- said photoresist being a layer having a thickness less than 500nm.

38. (Previously Once Amended and Currently Amended) Apparatus according to claim 37, characterized in that the at least one light source is a laser light source emitting light of a wavelength below 300nm.

39. (Previously Once Amended and Currently Amended) Hologram recorded in a recording medium according to claim 1, characterized in that a photoresist is employed whose refractive index at the exposure wavelength is greater than 1.6.